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FACTORS UNDERLYING THE CAPACITY FOR EXERCISE IN MALES AND FEMALES

BY

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The undersigned cerfity that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Factors Underlying the Capacity for Exercise in Males and Females," submitted by Arnold James Donovan in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

The purpose of this study was to examine males and females in order to supplement the present knowledge with physiologic bases for the differences in maximal aerobic power that exist between the sexes. Further to this it was hoped that data collected would provide norms for males and females on selected physiologic measurements.

Comparisons between the sexes were made on the following variables; age, height, weight, body composition, maximal oxygen consumption measured in l./min., ml./min./Kg. and ml./min./Kg. fat free, hemoglobin concentration, ventilatory equivalents, oxygen pulse and lung capacities and volumes.

Twenty healthy males and twenty healthy females enrolled as first year students in the Faculty of Physical Education acted as subjects for the study. Parameters measured were; body density, lung volumes and capacities, MVO_2 and hemoglobin concentration.

From this study it was concluded that significant differences occurred at the .01 level between the male and female subjects for the variables: height, weight, percentage fat, body density, lean body weight, functional residual capacity, vital capacity, expiratory reserve volume, MVO_2 l./min., MVO_2 ml./min./Kg., hemoglobin concentration, volume of air expired and oxygen pulse. No significant differences occurred at the .01 level between the male and female subjects for the variables: age, residual volume, MVO_2 ml./min./Kg. fat free, maximum heart rate and ventilatory equivalent. Significant correlations at the

.01 level were found between MVO_2 in l./min. and body weight, (.68) and MVO_2 in l./min. and lean body weight, (.75) among male subjects.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

It has been shown by Buskirk et al. (13), Coyne (19), Rasch and Pierson (63) and Welch et al. (81) that there is a significant correlation between maximal oxygen uptake and lean body weight. Coyne (19) and Welch et al. (81) found the correlation of maximal oxygen uptake with fat free body weight to be higher than the correlation of maximal oxygen uptake and body weight.

Body composition has been examined by Skerlj et al. (73), Miller et al. (57), Macnab et al. (53), Ljunggren et al. (51), Brozek et al. (10) and Metheny et al. (56). Where comparisons were made between men and women, it is generally concluded that 20 - 30 percent of the body weight in normal young women is comprised of fat and in normal young men this figure is 10 - 20 percent.

Holmgren (43) has stated that maximal oxygen uptake and transport is a product of dimensional factors (size of organs that compose this transport line) and functional capacities (related to the dimensions of the component and to its optimal function). Dimensional factors include the size of lungs (vital capacity, total lung capacity or functional residual capacity), and the dimensions of the cardiovascular system (blood volume, total hemoglobin, hemoglobin concentration, and heart volume).

When examining percentage differences, Macnab et al. (53) found that the values for men are, on the average, 50% higher than those for women when MVO_2 is expressed in litres per minute. This difference is reduced to 23% when expressed as ml./min./Kg. This difference is further reduced to 11% when MVO_2 is expressed in terms of fat free body weight. The conclusion from this was that weight and fat free weight tend to be an influencing factor causing differences in maximal work capacity between men and women. It was suggested by Macnab et al. (53) that another factor that could account for some of the difference is hemoglobin concentration. Others, Astrand and Saltin (6), Astrand (4), and Holmgren (43), suggest that some of this difference could be attributed to blood volume, cardiac output, lung capacity and maximum ventilation.

There is a need to supplement the existing body of knowledge regarding dimensional factors in normal healthy males and females and the resultant effect of these factors on maximal oxygen consumption.

The Problem

The purpose of this study was to compare males and females on the basis of dimensional factors (body composition, hemoglobin concentration, vital capacity, total lung capacity and on the functional capacities (ventilatory equivalent, maximum pulmonary ventilation, oxygen pulse and maximum heart rate) in order to ascertain the extent to which these variables contribute to intersexual differences in maximal oxygen consumption.

Specifically, a comparison between males and females was made on the following variables:

1. Age, height and body weight.
2. Body composition:
   a) Percent body fat.
   b) Fat free body weight.
3. Hemoglobin concentration.
4. Vital capacity and total lung volume.
5. Ventilatory equivalents.
6. Oxygen pulse.
7. Maximum heart rate.
8. Maximum pulmonary ventilation.
9. Maximal oxygen consumption:
   a) litres/min.
   b) ml./min./Kg. body weight.
   c) ml./min./Kg. fat free body weight.

Main Hypothesis

There are no significant differences at the .01 level of significance for the dimensional factors, body conposition, hemoglobin concentration and lung size or for the functional capacties of ventilatory equivalent, oxygen pulse, and maximal oxygen consumption when expressed in terms of l./min., ml./min./Kg. and ml./min./Kg. fat free.

Subsidiary Hypothesis

There are no significant correlations at .01 level between MVO_2 expressed in l./min. and any of the dimensional factors, body composition, hemoglobin concentration, height, weight and lung capacities.

Justification for the Study

It is known that differences exist between males and females in capacity to perform physical work. It is necessary to understand the physiological basis for these differences in order to select activities and training regimes based on sound rationale. The collection of normative data is of scientific interest for comparisons between races, sexes, or societies.

Delimitations

The study was limited to forty subjects randomly selected from the first year students enrolled in the professional program in the Faculty of Physical Education at the University of Alberta, Edmonton.

The collection of data was restricted to the following variables: age, height, weight, body composition, lung volumes and capacities, hemoglobin concentration, maximal heart rate and maximal oxygen consumption.

Limitations

The room temperature and humidity were not controlled. Subjects were told to refrain from strenuous activity, eating or smoking prior to the testing, however this was not strictly enforced.

Definition of Terms

1. Fat Free Body Weight - the weight of the body if the amount of fat within the body, calculated using underwater weight, is subtracted from the total body weight (78).

2. Hemoglobin Concentration - an expression of grams of hemoglobin per 100 ml. of blood (30).

3. Vital Capacity - a static lung volume comprised of an inspiratory reserve volume, tidal volume, and the expiratory reserve volume (62).
4. Total Lung Capacity - vital capacity plus the residual volume (62).
5. Maximal Oxygen Consumption - an index of fitness which measures the ability of the cardio-respiratory system to take up, utilize and transport oxygen to the working muscles. According to Hill (41), maximal oxygen consumption is reached when oxygen intake per unit time has reached a maximum value that levels off due to limitations of the respiratory and circulatory systems.
6. Ventilatory Equivalent - the number of litres of air breathed (pulmonary ventilation) for every litre of oxygen consumed.
7. Maximal Oxygen Pulse - the gross oxygen intake divided by the corresponding heart rate (4).
8. Maximal Pulmonary Ventilation (S.T.P.D.) - the volume of air expired during the determination of MVO_2.

CHAPTER II

REVIEW OF THE LITERATURE

Maximal oxygen consumption has been generally used as a reliable means of assessing man's maximal cardio-respiratory strength for set conditions of work and has been defined as "the oxygen forwarding capacity of the cardio-respiratory system" (43). It is not clear whether factors other than circulation affect this measure (19).

Maximal Oxygen Consumption and Body Composition

Adams (1) tested 60 subjects, 30 males and 30 females, for maximal oxygen consumption and correlated it to some anthropometric measures. The subjects were normal healthy adults ranging in age from 20 - 52 years. The maximal oxygen consumption, as measured on the bicycle ergometer, correlated 0.76 with body weight and 0.71 with lean body weight.

Allsopp et al. (3), in a recent study, examined two groups of non athletic males on a progressive bicycle ergometer test and correlated the oxygen uptake values to body weight. The subjects were put into two groups on the basis of body weight. Those below 65 Kg. were put in one group and had a mean body weight of 59 Kg. Those over 65 Kg. were put in another group and had a mean weight of 81 Kg. A comparison between light and heavy subjects showed the heavy subjects consuming more oxygen at each work level but the differences were not significant.

Astrand (4) in studies on age and sex differences found, with 115 male subjects ranging in age from 4 - 33 years, a correlation of 0.98 between oxygen consumption and body weight. For 36 females ranging in age from 4 - 24 years and weighing less than 40 Kg., the correlation coefficient was 0.96. For 76 females, ages 12 - 25 years and average weight of over 40 Kg., the correlation coefficient was 0.86.

Buskirk and Taylor (13) measured maximal oxygen consumption on 54 male subjects, ages 18 - 29. Of the subjects, 46 were students and 13 were soldiers. The MVO_2 results obtained on a treadmill correlated 0.85 with fat free body weight and 0.45 with cell mass. Active tissue (fat free body weight) was defined as At = M - (F + B + EW) where M = body mass, F = fat mass, B = bone mineral mass, EW = mass of water in thiocyanate space. Cell mass was defined as a body compartment similar to active tissue, differs from active tissue since fluid volumes alone are used in its calculation. It was condluded that when VO_2 is used to examine the capacity to perform exhausting work, the values should be expressed as VO_2 per Kg. of body weight; when the test is used to examine the performance of the cardio-respiratory system, the values should be expressed as VO_2 per Kg. of fat free weight.

Cotes and Davies (17) measured MVO_2 using 79 male factory workers and coal miners (average age 55.6 years, average weight 67.5 Kg.). Work was performed on a Bicycle ergometer. A high positive correlation was reported between body weight and oxygen consumption.

Coyne (19) determined MVO_2 on 30 active male subjects (mean age 23.1, mean weight 75.05 Kg.) by having them run on a treadmill. It was found that the correlation, (r = 0.39) between fat free body weight and MVO_2 was the only body mass characteristic significantly correlated

(P = 0.05).

Mahadeva et al. (54) studied the energy expenditure of 50 persons varying in size, race, sex and age. The males and females performed two different kinds of physical activity. The first was a stepping test which measured external work, the second was walking. They found that energy expenditure during stepping or walking can be closely predicted from a knowledge of body weight. No significant increase in precision is gained by also taking into account height, age, sex, race or resting metabolism.

Rasch and Pierson (63) measured oxygen consumption in 21 males (average weight 73.95 Kg.) by a treadmill walk. The only significant correlation (P. greater than .01) was between body weight and oxygen consumption (r = 0.65). A non significant (P = .01) correlation of r = 0.54 was found between fat free body weight and MVO_2.

Seltzer (70) in testing 34 males (ages 20 - 38 years) on an exhaustive treadmill run found a correlation of 0.88 between body weight and MVO_2. It was concluded that "there appears to be relation of a constitutional nature between morphology of individuals and their oxygen consumption".

Welch et al. (81) determined MVO_2 on 28 healthy males (mean age 23.7 years, mean weight 75.3 Kg.) by a treadmill run in a manner described by Taylor et al. (77). The following correlations were found with maximal oxygen uptake: body weight, r = 0.59; body weight minus fat, r = 0.65; body weight minus fat minus bone, r = 0.64.

Wilmore (82) tested 30 healthy males (mean age 22.2 years, mean weight 77.23 Kg.) twice on a bicycle ergometer and correlated each mean separately to various morphological measures. The following correlations

are based on the greater of the two MVO_2 measures. MVO_2 correlated to body weight, r = 0.69 and with lean body weight the correlation was r = 0.77.

Body Composition

Sloan (74) summarizes selected information on body composition for young men as follows:

TABLE I

PERCENTAGE FAT VALUES: MALES

Year	Authors	Country	No. of Subjects	Age (yrs.)	Fat %
1951	Brozek & Keys	U.S.A.	133	20.3 ± 1.9	10.9
1957	Riendeau et al.	U.S.A.	61	17 - 31	13.0
1962	Howell et al.	U.S.A.	133	20.9 ± 2.7	18.7
1965	MacMillan et al.	Scotland	24	18 - 22	10.7
1967	Sloan	S. Africa	50	18 - 26	10.8

Sloan explains the value reported by Howell as being high due to the Rathbun-Pace formula in the calculation of percentage fat.

If one is to disregard the formulae used to estimate percent body fat, males in Table II have a range of 9.32% to 21.30% with an average of 14.36%. The females including athletes have a range of 16.8% to 28.69% with an average of 23.70%. On the average, independent of the formula used to determine percentage fat, activity status and age, females exhibit 65.4% more body fat than do males.

The following table shows in summary form some body composition values for males.

TABLE II

SUMMARY OF FAT PERCENTAGES IN NORMAL MALES

Year	Authors	No. of Subjects	Age (Yrs.)	Fat %	Formula*	R.V.**
1958	Welch et al. (81)	28	23.70	15.10	Brozek (11)	M.
1969	MacNab et al. (53)	24	19.97	12.74	Brozek (11)	E.
1968	Wilmore & Behnke (84)	54	22.69	15.03	Rath. (64)	M.
1968	Wilmore & Behnke (84)	54	22.69	15.28	Siri (71)	M.
1968	Wilmore & Behnke (84)	54	22.69	09.32	Brozek (11)	M.
1952	Miller & Blythe (57)	48	24.30	15.10	----	-
1953	Brozek & Keys (11)	133	20.30	10.93	Brozek (11)	E.
1953	Brozek & Keys (11)	122	49.00	21.30	Brozek (11)	E.
1967	Durnin & Rahaman (23)	60	22.00	13.50	Siri (71)	E.

* Formulae used: Rath. = Rathbun-Pace; Brozek = Brozek-Keys.

** R.V. = residual volume; E = estimated; M = measured.

The following table shows in summary form some body composition values for females.

TABLE III

SUMMARY OF FEMALE BODY COMPOSITION VALUES FOR NORMAL NON-ATHLETES AND ATHLETES

Year	Authors	No. of Sub.	Age (Yrs.)	Class*	Fat %	Formula**	R.V.+
1969	Macnab et al. (53)	24	18.67	N	23.40	Brozek (11)	E.
1967	Conger & Macnab (16)	40	19.40	A	26.00	Rath. (64)	-
1967	Conger & Macnab (16)	40	18.60	N	25.20	Rath. (64)	-
1969	Moody et al. (58)	5	21,80	-	21.80	---	-
1961	Young et al, (87)	94	20.36	N	28.69	Rath. (64)	M.

TABLE III CONTINUED

Year	Authors	No. of Subs.	Age (Yrs.)	Class*	Fat %	Formula**	R.V.+
1961	Young et al. (87)	94	20.36	N	27.13	---	M.
1961	Young et al. (87)	94	20.36	N	24.92	Brozek (11)	M.
1967	Durnin & Rahaman (23)	45	21.70	-	24.20	Siri (71)	E.
1964	Conger (15)	35	19.94	-	24.86	Rath. (64)	E.
1969	Sprynarova & Parizkova (76)	10	17.23	A	16.80	Brozek (11)	-
1969	Sprynarova & Parizkova (76)	10	18.95	A	19.20	Brozek (11)	-
1968	Katch et al. (46)	5	---	A	20.10	Brozek (11)	-
1968	Katch et al. (46)	10	---	A	22.80	Brozek (11)	-

* Class = classified as N (non-athlete) or A (athlete).

** Formulae used: Brozek = Brozek-Keys; Rath. = Rathbun-Pace.

\+ R.V. = residual volume; M = measured, E = estimated.

Hemoglobin Concentration

Astrand (4) determined oxygen consumption, cardiac output, stroke volume, oxygen content of arterial blood and hemoglobin concentration in 11 women and 12 men, ages 20 - 31 years, all were classed as active college students. On both maximal and sub-maximal exercise, the women had a higher cardiac output per litre oxygen consumed than the men. Astrand concludes that this can be explained by a lower concentration of hemoglobin in the blood of women subjects.

Larsen (48) examined the blood of 1,624 male military draftees all aged 19 and found a mean hemoglobin concentration of 15.80 gm./100 ml., S.D. ± 1.00. The analysis was done colorimetrically using capillary blood.

Natvig (60) examined capillary blood of 312 male factory workers, ages 15 - 21 years, and found a mean hemoglobin value of 14.63 gm./100 ml. ± 0.05. The analysis was done colorimetrically.

Hawkins et al. (36) collected hematologic data on 1,308 males (ages 6 - 98 years) and 1,424 females (ages 6 - 94 years). Among children, 6 - 14 years old, the value increased from about 13 to 14 gm./100 ml. and there were no significant differences between boys and girls. The average value was 13.5 gm./100 ml. In females between the ages of 14 - 20 years the hemoglobin values decreased slightly, reaching about 13 gm./100 ml. In the males of corresponding ages, there was an increase to about 15 gm./100 ml. In both sexes these values were reached at about age 20 and remained characteristic throughout the third decade of life. Hemoglobin values in men between 20 and 60 years were typically 14.5 to 15 gm./100 ml., the higher values tending to occur among the younger men. After the firth decade there was a progressive and marked decrease to an average of 12.1 gm./100 ml. in men between 80 and 90 years of age. In females 20 years old and above, the average hemoglobin values remained near 13 gm./100 ml. In his study, Hawkins presents a review of various hematologic studies and lists the reported values for hemoglobin concentration. Hawkins points out that the methods used to evaluate hemoglobin concentration were "sufficiently similar" to justify comparison of these values with one another(note: these values in Table IV).

Gruber (31) reports on 25 female subjects between the ages of 18 - 24 years, a mean hemoglobin concentration of 13.67 ± .59 gm./100 ml.

TABLE IV

HEMOGLOBIN LEVELS AMONG MALES

Age	No.Subj.	Hb gm.%	Locality	Reference
16 - 25	137	15.1	Hawaii	Hamre, 1942
not given	111	15.8	Cleveland	Myers, 1939
17 - 23	25	15.9	Philadelphia	Belk, 1936
17 - 25	411	15.2	Boston	Heath, 1948
19 - 28	77	16.2	Sydney	Wardlaw, 1941
19 - 30	51	15.6	Norway	Linneberg, 1935
16 - 59	539	16.0	U.S.A. & Europe	Wintrobe, 1933 & 1951

Holmgren (43) compares 10 trained young men and women on the basis of a number of anthropometric, circulatory and respiratory values that are classified as either static dimensions or functional capacities. The females had a mean hemoglobin concentration and a maximal oxygen consumption of 13.09 gm./100 ml. and 2.59 l./min. respectively. The corresponding values for the males were 14.96 gm./100 ml. and 3.94 l./min. A mean of the male and female hemoglobin concentration values was correlated to a mean of their maximal oxygen consumption values with a resulting correlation coefficient of 0.68 (significant at P = 0.001).

Cullumbine (20) correlated hemoglobin concentration and various components of physical fitness. These components include speed in running 100 yards, strength, pulse response to moderate exercise, severe exercise and prolonged moderate exercise. The subjects numbered 200 and ranged in age from 14 - 20 years. They include 120 males and 80 females. The correlation coefficient calculated for hemoglobin concentration (taken before exercise) and response to moderate exercise (pulse index)

was - .072 and was not significant. The correlation between hemoglobin concentration and response to severe exercise (both endurance time and pulse index) was r = .17 and - .11 respectively. Neither of these were significant. Endurance times of 46 males for prolonged moderate exercise were correlated with hemoglobin concentration. The result was a significant correlation (P = 0.01) of r = .44. It was concluded that the higher the concentration, the greater the endurance time.

Hawkins et al. (36) lists reported values for hemoglobin concentration among females as they appear in Table V.

TABLE V

HEMOGLOBIN LEVELS AMONG FEMALES

Age	No.Subj.	Hb gm.%	Locality	Reference
12 - 19	258	12.2	Minnesota	Leichsenring, 1941
not given	48	13.0	Cleveland	Myers, 1939
15 - 22	44	13.6	Mississippi	Haworth, 1951
17 - 21	1080	12.0	Toronto	Hawkins, 1947
17 - 24	4550	13.4	North C., U.S.A.	Ohlson, 1944
17 - 22	161	13.8	Amherst, Mass.	Gutowska, 1946
17 - 25	52	13.2	Lincoln, Neb.	Chaloupka, 1951
17 - 26	352	13.8	Saskatoon, Sask.	Hawkins, 1948
18 - 23	25	13.5	Philadelphia	Belk, 1936
17 - 68	403	14.0	U.S.A. & Europe	Wintrobe, 1933 & 1951
19 - 30	60	14.1	Norway	Linneberg, 1935

Maximal Oxygen Consumption of Males and Females

Macnab et al. (53) examined differences in maximal and submaximal work capacity in young men and women. Table VI gives the results of a maximal treadmill run and a bicycle ergometer test after the method

described by Macnab et al.(53).

TABLE VI

MALE AND FEMALE COMPARISONS ON
MAXIMAL AEROBIC POWER

	No.	Sex	Age (Yrs.)	Ht. (in.)	Wt. (Kg.)	MVO_2 l./min.	ml./min./ Kg.	ml./min./ Kg. Fat Free
Mean	24	F	18.67	65.28	59.24	*2.32	39.06	50.42
S.D.			± .63	± 2.10	± 5.70	± .41	± 5.05	± 5.97
						**2.12	35.67	46.87
						± .41	± 5.59	± 7.20
Mean	24	M	19.97	70.59	76.10	*3.92	51.71	59.41
S.D.			± 1.16	± 2.39	± 8.80	± .58	± 5.13	± 5.86
						**3.52	46.47	53.31
						± .61	± 6.25	± 6.55

* Treadmill test.

** Bicycle Ergometer test.

The authors conclude, on the basis of data in Table VI, that weight and fat free weight might have some influence in the difference in maximal work capacity in men and women. They further suggest that hemoglobin concentration appears to be an additional factor that needs examining as it may account for the balance of the percent difference in MVO_2 between men and women.

Metheny et al. (56) evaluated oxygen consumption in 17 females, aged 18 - 27 years, and 30 males, aged 19 - 23 years. The test consisted of exhaustive treadmill running at 7 m.p.h. at an 8.6% grade for five minutes or until the subjects were unable to continue. It was found that at a maximal heart rate of 194 the men had reached an oxygen

consumption of 40.9 cc./min./Kg.

In Astrand's studies (4), comparisons were made between men and women for oxygen consumption as determined on a bicycle ergometer. The results for the 16 - 33 year old group are summarized in Table VII.

TABLE VII

MVO_2 COMPARISONS ON MALES AND FEMALES
AGES 16 TO 33 YEARS

Age Range	Sex	No.	MVO_2 l./min. Mean	S.D.	MVO_2 ml./min./Kg. Mean	S.D.
16 - 18	M	9	3.68	± .49	57.6	± 4.3
16 - 17	F	10	2.71	± .29	47.2	± 2.6
20 - 33	M	42	4.11	± .29	58.6	± 4.1
20 - 25	F	44	2.90	± .25	48.4	± 3.2

Cotes and Davies (17) examined some of the factors underlying the capacity for exercise in men and women. The subjects ranged in age from 18 - 28 years and included male athletes and male and female factory worker. Table VIII summarizes some of the data. MVO_2 values were obtained using a bicycle ergometer.

TABLE VIII

COMPARISON OF MVO_2 VALUES IN NORMAL
MALES AND FEMALES AND MALE ATHLETES

	Factory Workers Male	Factory Workers Female	Male Athletes
No.	23	20	3
Ht. (m.)	1.76	1.62	1.80
Wt. (Kg.)	71.4	55.0	91.6
MVO_2 l./min.	3.4	2.2	4.6
Vital Cap. (l.)	5.66	3.66	6.37

They concluded that for healthy British subjects, aerobic capacity may be described by linear regression equations based on functional dimensions including vital capacity, ventilation and cardiac frequency at an oxygen intake of 1.5 l./min. - 1 and the width of the muscle mass of the thighs. The equations may be extended by additional terms including ventilatory capacity: the gas transfer factor for the lungs and total body hemoglobin.

Knuttgen (47), in attempting to predict maximal oxygen consumption from sub-maximal steady state work loads, tested 95 males and 95 females, ranging in age from 15 - 19 years. The average male age 16.10 years and the average female age was 16.7 years. He found an average oxygen consumption in males and females of 3.34 litres and 1.89 litres respectively. These means were significantly different (P = .01). The average maximal oxygen consumption of the girls was 57% that of the boys. It was 67% that of the boys when the aerobic capacity was expressed in terms of body weight. The following table, taken from Knuttgen's study, shows selected correlation coefficients.

TABLE IX

COEFFICIENTS OF CORRELATION WITH
MEASURED MAXIMAL OXYGEN CONSUMPTION

	Max. VO_2	
	Female	Male
Height	.35	.51
Weight	.48	.61
$P.W.C._{170}$	.65	.77
Wt. & $P.W.C._{170}$	.71	.86

Knuttgen concluded that the prediction of aerobic capacity from steady state heart rate reactions to sub-maximal work was enhanced by including body weight in the calculation.

Hermansen and Andersen (39) compared male and female athletes on certain physiologic characteristics. The following table shows some of the results.

TABLE X

COMPARISON OF NORMAL MALES AND FEMALES WITH MALE AND FEMALE ATHLETES

	Sex	No.	Age (Yrs.)	Wt. (Kg.)	Max. VO_2	ml./min./Kg.
Athletes	M	14	27.7	66.7	4.8 ± 1.4	71 ± 1.8
Students	M	12	23.4	73.1	3.2 ± .10	44 ± 1.1
Athletes	F	5	25.1	61.6	3.3 ± .19	55 ± 1.4
Students	F	12	22.6	61.1	2.3 ± .08	38 ± 0.8

Male athletes average 50% higher than male students and female athletes are 44% higher than female students. On this same parameter, the male students averaged 40% higher than the female students; this was reduced to 16% when expressed on the basis of weight. The male athletes average 45% higher than the female athletes which is reduced to 30% when comparing subjects on a body weight basis. Hermansen and Andersen conclude that the difference between the males and females, in this study, among the athletically trained subjects is greater than those who live sedentary lives.

Ventilatory Equivalents

As defined in Chapter I, ventilatory equivalent is the ratio of air expired in litres/min. (S.T.P.D.) to oxygen consumed in litres per minute. Therefore, the lower the value, the more efficient the individual.

Astrand (4) examined 88 males and 101 females and reports the values that appear in Table XI.

TABLE XI

VENTILATORY EQUIVALENTS
FOR MALES AND FEMALES

		Age Groups						
	Sex	10-11	12-13	14-15	16-18	16-17	20-25	20-33
No. Subjects	M	13	19	19	9	---	---	40
	F	13	13	11	----	10	44	---
Vent. per	M	26.1	24.8	22.3	21.1	---	----	20.6
litre O_2 Intake	F	26.6	24.6	24.4	----	25.1	24.5	----

Although it is not shown in Table XI, Astrand found that younger girls, 4 - 6 years, have a smaller ventilation than boys of the same age (31 and 34 litres per litre oxygen intake respectively) for submaximal and maximal exercise. The boys and girls have about the same ventilation until the age of 14 (approximately 25 litres for both groups 12 - 13 years). The older females average 24 - 25 litres and the males 21 litres. He found the difference between male and female adults to be significant and concludes the relatively higher ventilation of females than males after puberty is "difficult to explain".

Knuttgen (47) collected data on 95 males and 95 females between the ages of 15 - 18 years. The females were an average of 16.7 years while the males averaged 16.1 years of age. He reports ventilatory equivalents for males and females of 42.5 ± 5.0 and 44.6 ± 6.2 litres. The mean differences were statistically significant at the .05 level.

Moody et al. (58) tested 5 lean (average age 19.4 years, weight 54.2 Kg., % fat 21.8) and 5 obese (average age 18.4 years, weight 92.1 Kg., % fat 44.0) college women. The ventilatory equivalents for the lean and obese women were 31.9 ± 6.2 and 33.2 ± 3.6 litres per litre oxygen consumed respectively. No tests for significant differences were reported.

Oxygen Pulse

Astrand (4) examined oxygen pulse in 15 males and 15 females. He concluded that, even at maximal heart rates of approximately 200 beats/min., the blood circulation is fully effective as far as oxygen transport is concerned. He explained that the continuous increase in oxygen transport per pulse beat at increasing heart rate can be explained through an increase in the A - VO_2 difference, or in the stroke volume, or through an increase of both at the same time.

In a study of 5 lean women (average age 19.4 years, weight 54.2 Kg., and % fat 21.8) and 5 obese women (average age 18.4 years, weight 92.1 Kg., and % fat 44.0), Moody et al. (58) found average oxygen pulse values of 10.5 ml. and 13.7 ml. respectively. The MVO_2 values reported by Moody were means of maximal values obtained by walking, a progressive level walk to determine precent grade required to reach a

maximal level, a run on a treadmill and a bicycle ergometer.

Hermansen and Andersen (39) examined male and female students as well as male and female athletes and reported oxygen pulse values. Table XII gives some characteristics of the subjects along with the oxygen pulse values. Maximal values were determined on a bicycle ergometer.

TABLE XII

OXYGEN PULSE VALUES FOR MALE AND FEMALE STUDENTS AND ATHLETES

	Sex	No.	Age (Yrs.)	Max. Heart Rate	Max. O_2 Pulse
Athletes	M	14	27.7	178 ± 1.8	27.2 ± 1.0
Athletes	F	5	25.1	186 ± 3.6	17.8 ± 0.9
Students	M	12	23.4	189 ± 2.4	17.0 ± 0.5
Students	F	12	22.6	203 ± 2.8	11.3 ± 0.5

CHAPTER III

METHODS AND PROCEEDURES

Sample

Twenty healthy males and twenty healthy females, randomly selected from the first year undergraduate students enrolled in the professional program in the Faculty of Physical Education, the University of Alberta, acted as subjects.

Testing Order

The testing was conducted over a period of three weeks. The subjects were randomly divided into two blocks with twenty in each block. Block One was tested first over a 10 day period, then Block Two was tested.

Subjects participated in two testing sessions. During the first testing session body density was estimated by an underwater weighing technique. Lung volumes were also measured at this time. During the second session blood samples were taken to determine hemoglobin concentration. Maximal oxygen consumption was subsequently determined by the use of a bicycle ergometer. Order of testing was not critical since there was no potential training effect to eliminate.

Calculation of Body Density

The equipment used in determination of body density is listed below:

1. Water tank.

2. Eighteen pound lead weight belt.
3. Schaevitz Bytrex model JP-200 strain guage.
4. Aluminum chair attached to strain guage and suspended in the tank.
5. Collins spirometer.
6. Godart Pulmotest with twin spirometers and a Godart Analysor (type 44A-2).
7. Helium.
8. Oxygen.
9. Health-o-meter balance scales.

Proceedure

The subjects wore close fitting bathing suits and were not permitted to wear bathing caps. Upon entering the laboratory, the subject was first weighed and then entered the water tank and stood so that the water was at neck level. With the subject in this position, a nose clip and mouthpiece were put in place and the subject was allowed to continue breathing room air. At the end of an expiration the subject was switched over to the closed circuit. The hose through which the subject breathed was connected to a spirometer of a known volume, which contained a known volume of helium. The residual volume of air in the lungs was determined from the neasured functional residual volume. Following the attainment of an equilibrium of helium in the spirometer and the lungs, the gas temperature was recorded. The subject remained on the closed circuit and vital capacity was determined taking the highest of three readings. The subject was then disconnected from the closed circuit and sat in the chair with the weight belt across the

thighs. The water was again maintained at neck level. The removal of air bubbles from the subject's body was accomplished by having the subjects rub themselves. After a maximal inspiration, the subject pinched the nose and bent forward into the water until the head was completely immersed. The subject remained submerged until told to come up. This was repeated three times and the lowest reading recorded, after which water temperature and density were recorded. Once the subject's underwater weight had been determined, the body density was calculated (see appendix A). The calculation of percent body fat was estimated using the formula of Brozek and Keys (11) where:

$$\% \text{ Fat} = \frac{4.570}{\text{Body Density}} - 4.142$$

The subject then got out of chair and stood with the water at neck level. The subjects vital capacity was then measured taking the highest of three readings from a Collin's Spirometer.

Hemoglobin Analysis

Capillary blood was taken from the distal phalanx of the middle finger after cleaning with disinfectant. After the removal of the first drop, 0.20 ml. of blood was taken for the hemoglobin determination and added to 3.5 ml. of Drabkin's solution consisting of 1.000 gm. of sodium bicarbonate, 0.200 gm. of potassium cyanide and water to 1000 ml. After at least 30 minutes, the color of the solution was read in a Brauch and Loam photoelectric colorimeter.

Maximal Oxygen Consumption

In order to sufficiently load the cardio-respiratory centers to a maximal extent, large muscle groups must be engaged (40). For this reason stationary bicycle and treadmill exercises have been most

extensively used in determining maximal oxygen consumption (40). Before the subject performed the bicycle ride, the seat was adjusted to allow for individual variations in height. The pedal frequency was set at 50 revolutions per minute, being established by an electric metrome with a visual stimulus.

Male Subjects

The males pedalled for four minutes at a work load subjectively determined by the pre-exercise heart rate. The lower the heart rate, the higher the initial work load. During the last minute of the four minute ride, expired volumes were collected and during the last 15 seconds heart rate was determined. The subject then rested for five minutes during which time the collected volume of gas was analyzed for oxygen consumption. Subsequent work loads usually were increased by 300 K.p.m. to 450 K.p.m. depending on the response of the subject. These steps were repeated until there was no appreciable gain in oxygen consumption, that is 80 ml. min. or less (4). This was generally achieved at a heart rate of 185 ± 5 beats per minute.

Female Subjects

Same as outlined above for males except work loads were in most cases, less at given work intervals.

Gas Collection and Analysis

A four flap triple - J valve was used to allow the subject to breathe room air and expire only into Douglas bags. A rubber mouthpiece was fitted onto the valve and both were attached to a lightweight headgear which permitted easy attachment to the subject. Expired air

was analyzed for oxygen content with a Beckman E-2 oxygen analysor, and for carbon dioxide with a Godart Capnograph. The volume of air expired was collected for the last minute, or in the case of severe exhaustion for 30 seconds and measured with an American Meter Company Gasometer.

Heart Rate

The heart rate was recorded by means of a Sanborn electrocardiograph, using a six beat complex. Disc electrodes were used with the cups filled with Redux for better conductivity.

Calibration of Instruments

The gas analysors were calibrated prior to use each day and at regular intervals throughout each testing session. The calibration was done with samples of known oxygen content and known carbon dioxide content. As a further check, the sample calibration gases were analyzed individually by the technique of Scholander (65).

Statistical Procedures

An inter-variable correlation matrix was established using multiple regression analysis. The .01 level of significance was chosen for this test. A Fortran IV MULRØ 6 program was obtained from the Department of Educational Research.

A comparison between males and females was made for the variables; age, height, weight, body composition, lung volumes and capacities, hemoglobin concentration and $\dot{M}VO_2$ using a t - test. The t - test used was a simple test for significance of a difference between the means of two large uncorrelated samples as described by Ferguson (26). A test on homogenity of variance was done in the manner described by Edwards(24).

A FORTRAN IV ANOV 10' program was obtained from the Department of Educational Research. The .01 level of significance was accepted.

All programs were computed on the IBM 360/67 computer at the University of Alberta Computing Science Department.

CHAPTER IV

RESULTS AND DISCUSSION

Characteristics of the Subjects

Twenty healthy male and twenty healthy female subjects randomly selected from the population of first year undergraduate students enrolled in the professional program in the Faculty of Physical Education, the University of Alberta, participated in the study. Some characteristics of the subjects are given in Table XIII.

TABLE XIII

CHARACTERISTICS OF THE TEST SUBJECTS

		Mean	Standard Deviation	Range
Females				
	Age (yrs.)	18.64	1.08	17 - 21
	Height (in.)	64.54	3.11	58 - 72
	Weight (Kg.)	60.52	5.95	52 - 71
	Fat %	21.11	4.57	13.7 - 30.56
	Fat Free Wt. (Kg.)	47.81	4.85	41.29 - 54.56
	Hb gms. %	14.12	1.07	11.72 - 16.33
Males				
	Age (yrs.)	18.84	1.08	18 - 20
	Height (in.)	69.14	2.30	65 - 74
	Weight (Kg.)	76.04	8.79	60 - 91
	Fat %	10.96	4.79	1.70 - 17.62
	Fat Free Wt. (Kg.)	67.49	6.70	54.02 - 79.95
	Hb gms. %	16.42	0.858	14.07 - 17.75

The percentages of body fat calculated for the female subjects in this study are in good agreement with values reported for women of similar ages by Macnab et al. (53), Conger (15), Conger and Macnab (16), Moody et al. (58), Durnin and Rahaman (23) and Katch et al. (45). The results obtained by Young et al. (87) are also in good agreement when the Brozek-Keys formula is used (11). The average percentage body fat for the non-athletes examined in these studies is found in Table III and is 24.46% compared with 21.11% obtained in the present study.

Percentage of body fat for males in this study are also in good agreement with values reported by others in Table II. The average percentage body fat of studies reported in this table, excluding the 49 year olds examined by Brozek and Keys (11), was 13.93% as compared to 10.96% in the present study.

The slightly lower mean values for males and females in this study, as compared to averages in studies sighted above, could be due to; a chance occurrance in sampling, a slightly different formula in the estimation of percentage body fat, a different method of estimating body density or all of the above.

Hemoglobin Concentration

The mean hemoglobin value for the females of 14.12 gm./100 ml. found in the present study is somewhat higher than values for this age and sex reported by Hawkins et al. (36) which was 13 gm./100 ml. In an earlier study Hawkins et al. (35) reports a value of 12.0 gm./100 ml. which is also lower than that reported in the present study. Further to this, Leichsenring et al. (49) reports a value of 12.2 gm./100 ml. which is lower than the value presented in this study. Other authors

report values for hemoglobin concentration which are also less than the values found by this study, however they do compare more favorably. These include Haworth et al. (37), 13.6 gm./100 ml.; Ohlson et al. (61), 13.4 gm./100 ml.; Gutowska and Ellms (29), 13.8 gm./100 ml.; Chaloupka et al. (14), 13.2 gm./100 ml.; Belk et al. (8), 13.5 gm./100 ml.; Wintrobe (86), 14.0 gm./100 ml. and Gruber (31), 13.67 gm./100 ml.

In comparing the mean value for the males of 16.42 gm./100 ml. obtained in this study with others, values again tend to be somewhat higher than those reported in the literature. Larsen (48) reports a mean value of 15.80 for males all 19 years of age. Natvig (60) reported 14.63 gm./100 ml. for males aged 15 to 21 years, using the same method of analysis that was used in the present study. In Table IV for subjects aged 16 - 30 years reported on by Hamre, Belk et al., Heath, Wardlow and Linneberg, the mean value is 15.6 gm./100ml.

When measuring a variable such as hemoglobin concentration, it would seem imperative to outline explicity the method used, the time of day, and the activity level prior to the time of testing. For women the time of the menstrual cycle during which the sample is taken may have some effect.

The effect of the menstrual cycle on hemoglobin concentration has been studied by Gruber (31), Southam (75), Barker and Fowler (8), Guyton (30).

In Gruber's study of 25 females, ages 18 - 24 years, hemoglobin concentration did not fluctuate significantly throughout the menstrual cycle as testing was done on days two, nine, seventeen, and twenty-six of the cycle. This is significant in view of the fact that

during a normal twenty-eight day menstrual cycle estrogen levels reach a peak on day fourteen and again around day twenty-one (27) and estrogen has been shown by Southam and Gonzaga (75) to increase hemoglobin concentration.

Garlick and Bernauer (28) tested 18 undergraduate nurses on the Astrand-Ryhming bicycle ergometer test and compared heart rate, blood pressure and blood constituents before and after exercise on the first day of menstruation to values obtained on day fourteen during rest.

Hallberg (32) tested 137 female factory workers and found that hemoglobin concentration was reduced during menstruation only in a few subjects with a blood loss greater than 100 ml. each menstrual period. However, mean menstrual blood loss reported by Hallberg (32), Guyton (30), Barker and Fowler (7) was between 35 to 50 ml. The mean iron loss during menstruation has been reported by Elwood and Rees (25) as being between 12.2 and 13 mg. Hallberg (33) has calculated that with a normal daily iron intake and a hemoglobin concentration of at least 12 gm./100 ml., the iron balance in the body will be maintained with menstrual blood losses up to 63 ml. By way of summary, it is entirely possible that since the time of the female menstrual cycle was not taken into account, increased estrogen levels or higher than normal blood losses could account for the higher than normal mean hemoglobin concentration among the female subjects in this study.

Maximal Oxygen Consumption

Table XIV which follows compares the males and females on oxygen consumption.

TABLE XIV

MALE AND FEMALE MEAN VALUES FOR OXYGEN CONSUMPTION

	1./min.	ml./min./Kg.	ml./min./Kg. Fat Free
Males	3.95 ± 0.55	51.53 ± 5.52	58.58 ± 5.32
Females	2.61 ± 0.52	42.97 ± 7.97	54.74 ± 9.93

Table XV compares the results in Table XIV to similar studies. In all of the cases MVO_2 was determined using a bicycle ergometer.

TABLE XV

COMPARISON OF OXYGEN CONSUMPTION VALUES FOR MALES AND FEMALES

Author	Age Range or Mean	No.	Sex	MVO_2 1./min.	ml./min./Kg.	ml./min./Kg. F.F.*
Astrand (4)						
	16 - 18	9	M	3.68 ± 0.49	57.6 ± 4.3	
	16 - 17	10	F	2.71 ± 0.29	47.2 ± 2.6	
	20 - 33	42	M	4.11 ± 0.29	58.6 ± 4.1	
	20 - 25	44	F	2.90 ± 0.25	48.4 ± 3.2	
Macnab et al.						
	18.67	24	F	2.12 ± 0.41	35.67 ± 5.59	46.87 ± 7.20
	19.97	24	M	3.52 ± 0.61	46.47 ± 6.25	53.31 ± 6.55
Cotes & Davies (17)						
	18 - 28	20	F	2.2		
	18 - 28	23	M	3.4		
Present Study						
	18.64	20	F	2.61 ± 0.52	42.97 ± 7.97	54.74 ± 9.93
	18.84	20	M	3.95 ± 0.55	51.53 ± 5.52	58.58 ± 5.32

* F.F. = fat free body weight.

When examining Table XV it is evident that males exceed the females in all studies regardless of how MVO_2 is expressed. The males and females in the present study rank very high when compared to the other studies shown in Table XV. It was felt that reason for this was due to a random sampling of a better than average population according to fitness level. One possible reason for this occurrence could be due to the recent popularity of riding bicycles as a form of exercise.

Expired Volumes (S.T.P.D.), Maximal Heart Rates, Ventilatory Equivalents and Oxygen Pulse

Table XVI shows the data collected for the subjects in this study on expired volumes, maximal heart rate, ventilatory equivalents and oxygen pulse.

TABLE XVI

MEANS AND STANDARD DEVIATIONS FOR MALES AND FEMALES ON EXPIRED VOLUMES, MAXIMAL HEART RATES, VENTILATORY EQUIVALENTS AND OXYGEN PULSE

	E.V. (S.T.P.D.) (l./min.)	H.R.	V.E. (l.)	Oxygen Pulse (ml.)
Male	96.70 ± 19.60	194.4 ± 7.79	24.50 ± 3.60	20.36 ± 3.14
Female	71.84 ± 15.70	187.6 ± 9.06	27.00 ± 3.20	14.17 ± 2.38

In comparison with the information Astrand (4) presents, on ventilatory equivalents, to what is presented above, the present data shows an average of 27.00 l. for the females as compared with Astrand's values, 25.1 l. for the 16 - 18 year olds and 24.5 l. for the 20 - 25

year olds. The value of 44.6 for 15 - 18 year old females reported by Knuttgen (47) is quite high when compared to the values found in this study. Moody et al. (58) in studies of lean and obese women of the same approximate age as those in the present study, reports values as 31.9 and 33.2 litres respectively. When compared on the basis of ventilatory equivalents, the females in the present study rank high compared with those of other studies.

When comparing the males with those in other studies, Astrand (4) reports values of 21.1 litres for 16 - 18 year olds and 20.6 litres for 20 - 33 year olds. This compares with data on males in the present study reported as 24.50 litres. Values reported by Knuttgen (47) for males 15 - 18 years of 42.5 litres are considerably lower than those found in the present study.

Such large disparities in reported ventilatory equivalent values must be due to differences in characteristics of the subjects or to different conditions in the lab (humidity, temperature, etc.).

Moody et al. (58) reported a mean oxygen pulse of 10.5 ml. for lean women (mean age 19.4 years) and a value of 13.7 for obese women (mean age 18.4 years). The value in the present study of 14.17 ml. is somewhat higher than either of Moody's groups but compares more favorably with the value reported for obese women. Hermansen and Andersen (39) report oxygen pulse values for both male and female athletes and students. For the males he reports values of 27.2 ml. and 17.0 ml. for athletes and students respectively. This compares with 20.36 ml. for males in the present study. For female athletes, Hermansen and Andersen report values of 17.8 ml. and 11.3 ml. respectively. Values of 14.17 ml. places females in the present study somewhat lower

than the athletes but higher than the students.

Male-Female Comparisons

To test for significant differences between males and females a t - test was calculated after the method outlined in Ferguson (26).

TABLE XVII

MALE AND FEMALE DIFFERENCES

Variable	Mean Females	Mean Males	t - Value	Probability
Age (yrs.)	18.65	18.85	- 0.58	N.S.
Height (in.)	64.55	69.15	- 5.31	*
Weight (Kg.)	60.53	76.05	- 6.53	*
% Fat	21.11	10.96	6.85	*
Body Density	1.05	1.07	- 6.09	*
Lean Body Weight (Kg.)	47.81	67.50	-10.64	*
F.R.C. (1.)	1.49	1.94	- 3.84	*
V.C. (1.)	4.11	5.47	- 6.99	*
V.C. on Spirometer	3.71	5.01	- 6.48	*
E.R.V. (1.)	0.60	0.78	- 3.44	*
R.V. (1.)	0.88	1.16	- 2.40	N.S.
MVO_2 1./min.	2.61	3.95	- 7.88	*
MVO_2 ml./min./Kg.	42.97	51.53	- 3.95	*
MVO_2 ml./min./Kg. F.F.*	54.74	58.58	- 1.52	N.S.
Hb gm. %	14.13	16.43	- 7.49	*
Max. Pulm. Vent.**	71.84	96.70	- 4.43	*
Max. H.R.	187.6	194.5	- 2.56	N.S.
V.E. (1.)***	27.00	24.50	2.35	N.S.
Oxygen Pulse (ml.)	14.17	20.36	- 7.02	*

Abbreviations in Table XVII * F.F. = fat free body weight, ** = maximal pulmonary ventilation, *** V.E. = ventilatory equivalent, F.R.C. = functional residual capacity, V.C. = vital capacity as measured by Godart Pulmotest, V.C. on Spirometer = vital capacity as measured by Collins spirometer, E.R.V. = expiratory reserve volume, R.V. = residual volume.

The t - value required for significance at the .01 level with 38 degrees of freedom is 2.71. All means of the males were significantly different from the females on all variables except age, residual volume, MVO_2 expressed in ml./Kg. fat free body weight, maximum heart rate and ventilatory equivalents as shown in Table XVII.

A t - test is only a valid test to use if the separate variance estimates provided by the two samples are both estimates of the same population variance (24). A homogeneity of variance test was calculated in the manner described by Edwards (24). At the .01 level of significance F must equal 3.40. No such significant F was found. Therefore, the variances can be assumed to be equal.

Another useful treatment of the data obtained in the present study was to compare the percentage differences between males and females.

The percentage differences are expressed in terms of the values for male subjects exceeding the values for females. It is interesting to note that the percentage difference of 6.99 between males and females for oxygen consumed is not significant, however most studies (53), (4) and others report a significant difference. This, it is felt, is due to a chance occurrence in the selection of a better than average fitness level of the female sample.

TABLE XVIII

PERCENTAGE DIFFERENCES ON SELECTED MEASURES

	Males	Females	% Diff.
T.L.C.*	7.05	4.98	41.56
Weight (Kg.)	76.04	60.52	25.64
% Fat	10.96	21.11	- 48.08
Lean Body Weight	67.49	47.81	41.16
MVO_2			
l./min.	3.94	2.61	50.95
ml./Kg.	51.53	42.96	19.94
ml./Kg./F.F.	58.57	54.74	6.99
Hb gms. %	16.42	14.12	16.28
V.E.	24.50	27.00	- 9.25
Max. H.R.	194.4	187.6	3.62
O_2 Pulse	20.36	14.17	43.68

* T.L.C. = Total lung capacity.

It has been shown that the transport of oxygen in the human body is dependent on dimensional factors and functional capacities (42). Dimensional factors include the influence of the size of the organs that compose the oxygen transport system, the size of the pulmonary capillary bed, size of the vascular system, the maximal heart rate, and the concentration of hemoglobin in the blood. The dimensions of the lungs may be described by vital capacity, total lung capacity or functional residual capacity. The cardio-vascular system dimensions can be described by blood volume, total hemoglobin, hemoglobin concentration and heart volume. It has been shown by Holmgren (43) that the oxygen forwarding capacity is significantly correlated with all these different dimensional factors.

The functional capacity of the lungs can be described as being comprised of ventilation during determination of VO_2 max., and diffusing capacity of the lungs for carbon dioxide. The functional capacity of of the cardio-vascular system can be described by maximal cardiac output and stroke volume (43).

With the subjects in this study, no significant t - value was obtained when expressing MVO_2 in terms of fat free body weight. Male subjects were 6.99% higher than the females. This difference may be due to the higher total lung capacity, greater oxygen pulse, greater hemoglobin concentration, and the greater maximal pulmonary ventilation of the males.

Inter-Variable Correlations

Tables XIX and XX show the correlations that exist between the variables examined in this study for males and females.

The values of the correlation coefficient for different levels of significance with 19 degrees of freedom are: $P = .01$, $r = 0.549$; $P = .02$, $r = 0.503$; $P = .05$, $r = 0.433$; $P = 0.1$, $r = 0.369$.

In the case of the male subjects the only variables significantly correlated with maximal oxygen consumption at the .01 level are body weight $r = 0.68$, and lean body weight $r = 0.75$. For female subjects none of the variables correlate significantly with maximal oxygen consumption at the .01 level of significance. One would tend to support the idea of hemoglobin concentration correlating significantly with maximal oxygen consumption in view of its' role as an oxygen carrier in the blood; however, no such correlation was found with either sex. Total hemoglobin has been found to correlate significantly with MVO_2

(72). One possible explanation is that the total amount of hemoglobin in the body is related to body size (72). In the case of a small individual and a large individual in the same physical condition, they may have similar hemoglobin values. However, because of body size, the larger person would have a larger blood volume and hemoglobin volume and therefore a higher potential for oxygen consumption. Further to this, Sjostrand (72) has found that during physical training, both blood volume and hemoglobin volume increase with hemoglobin concentration remaining constant.

TABLE XIX

INTER-VARIABLE CORRELATIONS FOR MALES

	Age	Ht.	Wt.	% Fat	Body Density	Lean Body Wt.	F.R.C.	V.C.	V.C. Spir.	E.R.V.	R.V.	MVO 1./min.	Hb Gms. %
1	1.00	0.19	0.23	-0.19	0.25	0.15	-0.09	0.15	0.04	0.08	-0.12	0.20	0.20
2	0.19	1.00	0.67	0.22	-0.22	0.67	0.23	0.74	0.67	0.14	0.16	0.32	0.09
3	0.02	0.67	1.00	0.51	-0.47	0.88	0.34	0.67	0.57	-0.27	0.44	0.68	-0.19
4	-0.19	0.22	0.51	1.00	-0.95	0.05	0.12	0.09	0.09	0.03	0.10	0.07	-0.16
5	0.25	-0.22	-0.47	-0.95	1.00	-0.02	-0.13	-0.04	-0.04	-0.03	-0.11	-0.02	0.13
6	0.15	0.67	0.88	0.05	-0.02	1.00	0.32	0.73	0.62	-0.32	0.44	0.75	-0.13
7	-0.09	0.23	0.34	0.12	-0.13	0.32	1.00	0.24	0.19	0.11	0.90	0.07	0.24
8	0.15	0.74	0.67	0.09	-0.04	0.73	0.24	1.00	0.91	0.02	0.21	0.54	0.18
9	0.04	0.67	0.57	0.09	-0.04	0.62	0.19	0.91	1.00	0.12	0.13	0.44	0.19
10	0.08	0.14	-0.27	0.03	-0.03	-0.32	0.11	0.02	0.12	1.00	-0.31	-0.50	-0.03
11	-0.12	0.16	0.44	0.10	-0.11	0.44	0.90	0.21	0.13	-0.31	1.00	0.28	0.25
12	0.20	0.32	0.68	0.07	-0.02	0.75	0.07	0.54	0.44	-0.50	0.28	1.00	0.00
13	0.20	0.09	-0.19	-0.16	0.13	-0.13	0.24	0.18	0.19	-0.03	0.25	0.00	1.00

NOTE: No. 1 - 13 in the first column stand for variables which appear in the headings.

TABLE XX

INTER-VARIABLE CORRELATIONS FOR FEMALES

	Age	Ht.	Wt.	% Fat	Body Density	Lean Body Wt.	F.R.C.	V.C.	V.C. Spir.	E.R.V.	R.V.	MVO_2 l./min.	Hb gms. %
1	1.00	0.21	0.04	0.03	-0.04	0.02	0.39	0.47	0.39	0.12	0.39	-0.05	-0.16
2	0.21	1.00	0.62	0.10	0.00	0.53	0.57	0.66	0.68	0.26	0.52	0.16	-0.44
3	0.04	0.62	1.00	0.18	-0.01	0.81	0.36	0.70	0.63	0.35	0.24	0.36	-0.22
4	0.03	0.10	0.18	1.00	-0.95	-0.40	-0.12	0.02	-0.00	0.02	-0.15	-0.15	0.16
5	-0.04	0.00	-0.01	-0.95	1.00	0.53	0.14	0.08	0.08	-0.07	0.20	0.14	-0.10
6	0.02	0.53	0.81	-0.40	0.53	1.00	0.42	0.66	0.60	0.32	0.32	0.44	-0.32
7	0.39	0.57	0.36	-0.12	0.14	0.42	1.00	0.59	0.59	0.47	0.90	-0.19	-0.59
8	0.47	0.66	0.70	0.02	0.08	0.66	0.59	1.00	0.91	0.42	0.47	0.20	-0.38
9	0.39	0.68	0.63	-0.00	0.08	0.60	0.59	0.91	1.00	0.38	0.49	0.17	-0.40
10	0.12	0.26	0.35	0.02	-0.07	0.32	0.47	0.42	0.38	1.00	0.06	0.13	-0.51
11	0.39	0.52	0.24	-0.15	0.20	0.32	0.90	0.47	0.49	0.06	1.00	-0.29	-0.42
12	-0.05	0.16	0.36	-0.15	0.14	0.44	-0.19	0.20	0.17	0.13	-0.29	1.00	0.11
13	-0.16	-0.44	-0.22	0.16	-0.10	-0.32	-0.59	-0.38	-0.40	-0.51	-0.42	0.11	1.00

NOTE: No. 1 - 13 in the first column stand for variables which appear in the headings.

CHAPTER V

SUMMARY AND CONCLUSIONS

The main purpose of this study was to examine some of the physiologic characteristics of men and women in order to better understand their differences in the capacity for maximal aerobic work. The main characteristics examined were body composition, hemoglobin concentration, lung capacity, ventilatory equivalents, oxygen pulse, and maximal oxygen consumption. The subsidiary problem was to investigate the relationship between maximal oxygen consumption and all the other variables for both males and females.

Twenty female subjects and twenty male subjects participated in the study. They were all enrolled as first year undergraduate students in the professional program of the Faculty of Physical Education, the University of Alberta. The subjects were randomly selected and randomly tested. The subjects' body density was measured by the hydrostatic weighing technique. Body fat was calculated from the body density measurement, by the formula derived by Brozek and Keys (11). A sample of capillary blood was taken and analyzed for hemoglobin and immediately afterward maximal oxygen consumption was determined with the subject pedalling a bicycle ergometer.

The test data was first analyzed for homogeniety of variance in a matter described by Edwards (24). A t - test for significant differences between means was done for all variables in a manner described by Ferguson (26). These variables included all measures of body

composition, age, height, weight, lung volumes, hemoglobin concentration, ventilatory equivalents, oxygen pulse, maximum pulmonary ventilation and maximum heart rates. An inter-variable correlation matrix was calculated using the Pearson product-moment correlation coefficient (26), for all data collected.

Conclusions

1. There were significant differences at the .01 level of significance between males and females for the variables of body composition, hemoglobin concentration, vital capacity and oxygen pulse. No significant difference was found between ventilation equivalents and MVO_2 when expressed in terms of ml./min./Kg. fat free body weight.

2. In correlating maximal oxygen consumption to age, height, body composition, lung volumes and hemoglobin concentration, the males had significant correlations of 0.68 and 0.75 for body weight and lean body weight respectively (P = .01).

Recommendations

It was felt that the cross sectional area of the leg muscles and $A\text{-}VO_2$ difference could be examined as possible reasons for the difference between college age men and women in their ability to perform maximal work aerobically.

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APPENDICES

APPENDIX A

SAMPLE CALCULATION SHEETS

ESTIMATION OF BODY COMPOSITION

Measurements	Pounds	Litres	Cubic Inches
Wt. in Air			
Vital Capacity (VC)			
Residual Volume (RV)			
Vol. Gastro Intestinal (VGI)			
Wt. in water (full inspiration)			

Calculations

* T.L.C. = _____(V.C.) + _____(R.V.) + _____(V.G.I.) = _____T.L.C. cu.in.

_____T.L.C. cu. in X .0362 = _____T.L.C. lbs.

True wt. = _____(wt. in water) + _____(T.L.C. lbs.) = _____

Body Volume = _____(wt. in air) - _____(True wt.) = _____

Body Density = _____(wt. in air) / _____(Body Vol.) X _____ Density of water

= _____

$$\% \text{ Fat} = \frac{4.570}{\text{Body Density}} - 4.142$$

Lbs. Fat = _____(% fat) X _____(wt.) = _____

Lbs. Fat Free wt. = _____(wt.) - _____(lbs. Fat) = _____

* T.L.C. = total lung capacity

PULMOTEST

Determining Lung Volumes and Capacities

Name_______________

Initial Helium _______________

Final Helium _______________

Gas Temperature _______________

Water Temperature _______________

$$\text{F.R.C.} = \frac{(\text{Initial He} - \text{Final He}) \times (\text{Dead Space } 9.37 \text{ l.})}{\text{Final He}}$$

= __________ L.

V.C. = __________ (m.m.) X __________ (Temp. Corr. Factor)

= __________ L.

E.R.V. = __________ (m.m.) X __________ (Temp. Corr. Factor)

= __________ L.

R.V. = __________ (F.R.C.) - __________ (E.R.V.)

= __________ L.

APPENDIX B

RAW SCORES

RAW DATA ON BODY FAT DETERMINANTS AND HEMOGLOBIN NORMS - MALE SUBJECTS

Subj.	F.R.C. (1.)	V.C. (1.)	V.C. (1.) Spirometer	E.R.V. (1.)	R.V. (1.)	Wt.in Kg.	% Fat	Body Density	Lean Body Wt.Kg.	HB gms. %
01	1.88	5.00	4.90	1.0016	0.8841	67.27	8.08	1.08	61.83	16.41
02	1.30	4.79	4.30	0.7990	0.5056	60.00	9.96	1.07	54.02	16.58
03	1.66	4.72	3.80	0.8245	0.8360	77.50	13.26	1.06	67.22	14.07
04	1.75	6.21	5.90	0.6659	1.0909	77.50	2.50	1.09	75.56	16.66
05	2.45	5.32	5.20	0.9513	1.5074	73.97	9.81	1.07	66.72	16.91
06	1.33	4.57	4.20	0.4770	0.8615	62.50	1.70	1.09	61.43	16.91
07	2.46	6.21	5.60	1.0524	1.4102	68.86	3.87	1.09	66.19	17.08
08	2.51	4.47	4.10	0.8562	1.6547	69.77	9.06	1.07	63.45	16.24
09	2.80	6.03	5.20	0.3460	2.4581	91.59	15.19	1.06	77.67	16.91
10	1.86	6.18	5.90	0.8929	0.9698	78.29	12.42	1.07	68.57	15.41
11	1.64	5.28	5.00	0.6408	1.0019	76.80	12.66	1.07	67.09	15.49
12	2.00	6.45	5.60	0.6956	1.3080	85.68	6.68	1.08	79.95	16.41
13	1.47	5.83	5.50	0.6697	0.8063	86.81	15.59	1.06	73.28	15.24
14	1.83	5.10	4.50	0.8245	1.0139	72.27	12.18	1.07	63.46	16.75
15	1.72	5.81	5.20	0.7632	0.9657	80.45	8.04	1.08	73.98	17.08
16	2.08	5.83	5.70	1.0147	1.0741	84.31	17.62	1.05	69.46	16.08
17	2.06	4.43	3.70	0.7293	1.3401	71.13	11.54	1.07	62.92	16.24
18	1.94	6.28	5.40	0.8929	1.0518	81.59	17.05	1.05	67.67	17.58
19	1.74	5.10	4.80	0.7610	0.9888	66.47	14.58	1.06	56.78	17.75
20	2.13	5.79	5.70	0.6897	1.4461	88.18	17.50	1.05	72.75	16.75
$\bar{X}$	1.93	5.46	5.00	0.7774	1.1587	60.52	10.96	1.06	67.49	16.42
S.D.	0.3958	0.6679	0.6965	0.1756	0.4133	8.79	4.79	0.0129	6.70	0.8582

RAW DATA ON BODY FAT DETERMINANTS AND HEMOGLOBIN NORMS - FEMALE SUBJECTS

Subj.	F.R.C. (1.)	V.C. (1.)	V.C. (1.) Spirometer	E.R.V. (1.)	R.V. (1.)	Wt.in Kg.	% Fat	Body Density	Lean Body Wt. Kg.	Hb gms. %
01	0.9672	3.39	3.00	0.5074	0.4598	53.06	15.99	1.06	44.58	15.24
02	1.35	3.38	3.00	0.4784	0.8770	55.45	25.39	1.03	41.37	14.90
03	1.41	4.40	4.00	0.9248	0.4863	63.40	17.50	1.05	52.31	11.72
04	1.48	4.26	3.50	0.5375	0.9455	64.09	15.99	1.06	53.84	14.57
05	1.81	3.60	3.10	0.6752	1.1363	60.45	16.16	1.06	50.68	13.23
06	1.03	3.92	3.00	0.3827	0.6523	57.72	24.08	1.04	43.82	14.90
07	1.26	3.77	3.40	0.5074	0.7603	52.15	18.40	1.05	44.88	13.98
08	1.21	4.31	3.80	0.6394	0.5803	71.81	25.22	1.04	53.70	14.57
09	1.94	4.88	4.80	0.5708	1.3701	71.81	25.09	1.04	53.79	12.73
10	1.37	4.00	3.90	0.5360	0.8366	55.56	25.68	1.03	41.29	14.32
11	1.29	3.75	3.30	0.6360	0.6564	63.18	30.56	1.02	43.87	14.99
12	1.74	4.84	4.30	0.5740	1.1758	69.09	21.03	1.05	54.56	13.90
13	1.37	3.57	3.60	0.4465	0.9247	55.90	13.70	1.06	48.24	14.90
14	1.39	4.69	4.40	0.6927	0.6962	65.00	20.95	1.05	51.38	16.33
15	1.59	4.01	3.50	0.6059	0.9938	55.54	24.21	1.04	42.02	14.74
16	1.17	3.64	3.50	0.5708	0.6078	59.31	18.93	1.05	48.08	14.57
17	1.60	3.58	3.50	0.4757	1.1270	53.86	19.30	1.05	43.46	13.56
18	1.33	4.31	3.90	0.7031	0.6275	57.95	26.57	1.03	42.55	13.56
19	2.23	4.40	3.90	0.9513	1.2854	61.31	21.74	1.04	47.84	13.06
20	2.14	5.46	4.90	0.6525	1.4909	64.20	15.83	1.06	54.04	12.81
$\bar{X}$	1.48	4.10	3.71	0.6034	0.8844	60.52	21.11	1.04	47.81	14.12
S.D.	0.3410	0.5602	0.5603	0.1428	0.3010	5.95	4.57	0.0120	4.85	1.07

RAW SCORES - MAXIMAL OXYGEN CONSUMPTION - MALE SUBJECTS

Subject	Bicycle Load KPM/min.	Heart Rate	% Oxygen	% Carbon Dioxide	Vol. Exp. S.T.P.D.	O_2 Uptake l./min.	V.E. l./min.	O_2 Pulse
01	1200	167	17.02	3.3	64.41	2.62		
	1500	195	17.20	3.1	85.45	3.33	25.66	17.07
02	1200	191	16.30	3.4	54.60	2.71		
	1350	214	16.72	3.2	73.68	3.30	22.32	15.42
03	1200	161	16.45	3.6	51.89	2.45		
	1500	180	16.60	3.4	68.14	3.12		
	1650	195	17.17	3.0	95.00	3.76	25.26	19.28
04	1050	132	16.30	3.2	51.78	2.59		
	1350	161	15.75	3.5	65.91	3.71		
	1650	187	16.72	3.2	106.57	4.77	22.34	25.51
	1800	180	17.20	2.4	111.28	4.55		
05	1350	173	16.27	3.4	62.00	3.09		
	1500	187	18.22	1.9	130.31	3.81		
	1650	195	16.90	2.9	89.64	3.88	23.10	19.89
06	1200	173	16.37	3.3	53.09	2.59		
	1500	187	16.30	3.5	67.73	3.34		
	1650	191	17.12	2.8	92.45	3.77	24.52	19.74
07	1200	173	16.62	3.2	54.37	2.50		
	1500	195	16.67	3.2	71.06	3.22	22.06	16.51
08	1200	164	16.52	3.2	49.23	2.32		
	1500	187	16.77	3.2	70.98	3.13		
	1650	191	16.60	2.9	67.10	3.16	21.23	16.54

RAW SCORES - MAXIMAL OXYGEN CONSUMPTION - MALE SUBJECTS

Subject	Bicycle Load KPM/min.	Heart Rate	% Oxygen	% Carbon Dioxide	Vol. Exp. S.T.P.D.	O_2 Uptake l./min.	V.E. l./min.	O_2 Pulse
09	1200	141	15.27	3.2	51.55	3.25		
	1500	164	15.92	3.1	73.33	4.04		
	1650	180	16.00	3.3	88.72	4.76		
	1800	187	16.42	3.1	104.95	5.12	20.49	27.38
10	1200	141	1540	3.8	44.84	2.68		
	1500	187	17.05	3.0	94.50	3.89		
	1650	191	15.77	3.4	70.21	3.95	17.77	20.68
11	1200	167	16.47	3.3	59.16	2.82		
	1500	180	17.32	2.6	95.53	3.70		
	1650	184	17.72	2.2	112.29	3.90	28.79	21.20
12	1200	145	16.42	3.2	56.83	2.76		
	1500	164	16.27	3.1	71.88	3.64		
	1800	187	16.62	3.1	98.61	4.56		
	2100	191	17.47	2.5	122.83	4.56	26.93	23.87
13	1200	145	17.07	2.9	64.59	2.65		
	1500	173	16.92	3.1	81.00	3.44		
	1800	187	17.70	2.5	125.46	4.30	29.17	22.99
14	1200	164	15.70	3.2	54.07	3.12		
	1500	184	16.10	3.2	70.22	3.70		
	1650	187	16.60	2.9	83.93	3.95	21.24	21.12
15	1200	167	16.22	3.2	54.45	2.78		
	1500	180	16.22	3.3	72.83	3.70		
	1800	204	17.52	2.6	132.35	4.79	27.63	23.48

RAW SCORES - MAXIMAL OXYGEN CONSUMPTION - MALE SUBJECTS

Subjects	Bicycle Load KPM/min.	Heart Rate	% Oxygen	% Carbon Dioxide	Vol. Exp. S.T.P.D.	O_2 Uptake l./min.	V.E. l./min.	O_2 Pulse
16	1050	123	15.50	3.5	51.27	3.05		
	1350	145	15.25	3.8	55.29	3.42		
	1650	167	15.95	3.6	82.09	4.39		
	1800	204	16.77	3.1	100.49	4.46	22.53	21.86
17	1200	161	16.75	3.4	59.89	2.63		
	1350	180	16.95	3.1	71.48	3.01		
	1500	200	17.77	2.4	108.71	3.65	29.78	18.25
18	1200	158	17.12	2.9	62.85	2.54		
	1500	187	17.40	2.8	87.15	3.25		
	1650	187	17.50	2.3	97.96	3.66	26.76	19.57
19	1200	167	16.55	3.4	56.70	2.63		
	1500	195	17.05	3.2	83.49	3.39		
	1650	200	17.85	2.5	117.26	3.80	30.85	19.00
20	1200	180	16.62	3.1	62.62	2.90		
	1500	204	16.45	3.4	76.63	3.65	20.99	17.89

RAW SCORES - MAXIMAL OXYGEN CONSUMPTION - FEMALE SUBJECTS

Subject	Bicycle Load KPM/min.	Heart Rate	% Oxygen	% Carbon Dioxide	Vol. Exp. S.T.P.D.	O_2 Uptake l./min.	V.E. l./min.	O_2 Pulse
01	600	132	17.27	2.6	31.65	1.24		
	900	187	17.62	2.6	55.95	1.95	28.69	10.43
02	900	135	17.75	2.4	54.69	1.85		
	1050	180	17.82	2.4	68.36	2.25	30.38	12.50
03	600	141	17.00	2.4	34.32	1.49		
	900	164	17.27	2.5	52.72	2.09		
	1200	187	17.77	2.3	87.14	2.95	29.53	15.78
04	300	118	18.37	2.2	20.89	0.555		
	600	141	16.62	2.7	27.35	1.29		
	900	167	15.97	3.2	35.39	1.92		
	1200	195	16.55	3.2	60.10	2.82	21.31	14.46
05	600	132	16.32	2.7	32.04	1.63		
	900	173	16.82	2.8	51.46	2.29		
	1050	187	16.97	2.7	59.12	2.53	23.36	13.53
06	600	130	16.60	2.7	30.27	1.44		
	900	167	16.40	3.0	43.81	2.16		
	1050	184	16.85	2.8	57.35	2.53		
	1200	187	17.37	2.4	70.30	2.72	25.84	14.54
07	600	143	17.37	2.3	38.96	1.51		
	900	184	17.65	2.1	69.45	2.50		
	1050	204	17.82	2.2	83.83	2.81	29.83	13.77

RAW SCORES - MAXIMAL OXYGEN CONSUMPTION - FEMALE SUBJECTS

Subject	Bicycle Load KPM/min.	Heart Rate	% Oxygen	% Carbon Dioxide	Vol. Exp. S.T.P.D.	O_2 Uptake l./min.	V.E. l./min.	O_2 Pulse
08	900	187	17.07	2.9	48.95	2.01		
	1200	195	17.77	2.2	98.41	3.36	29.28	17.23
09	600	161	17.35	2.7	33.05	1.26		
	1050	204	17.37	3.0	59.38	2.20	26.99	10.78
10	600	130	16.47	2.9	29.10	1.41		
	1050	180	16.80	3.0	55.04	2.44		
	1200	187	17.20	2.6	68.30	2.75	24.83	14.71
11	300	117	16.95	2.3	18.31	0.812		
	750	161	16.67	2.8	39.63	1.842		
	1050	195	17.02	2.8	61.63	2.59	23.79	13.28
12	300	140	17.22	2.2	22.25	0.915		
	750	150	16.72	2.8	39.03	1.78		
	1050	165	16.70	2.8	54.78	2.52		
	1200	184	16.87	2.6	58.55	2.60	22.51	14.13
13	750	167	17.35	2.7	46.53	1.77		
	1050	191	17.82	2.5	69.21	2.26		
	1200	191	18.10	2.1	97.92	2.96	33.08	15.50
14	600	110	17.22	2.3	33.88	1.38		
	900	132	17.12	2.6	49.71	2.05		
	1200	184	17.80	2.2	89.10	3.01	29.60	16.36

RAW SCORES - MAXIMAL OXYGEN CONSUMPTION - FEMALE SUBJECTS

Subject	Bicycle Load KPM/min.	Heart Rate	% Oxygen	% Carbon Dioxide	Vol. Exp. S.T.P.D.	O_2 Uptake l./min.	V.E. l/min.	O_2 Pulse
15	600	155	17.02	2.6	31.50	1.34		
	900	187	17.27	2.6	50.67	1.99	25.46	10.64
16	600	136	15.40	3.2	25.48	1.56		
	900	161	15.80	3.3	41.37	2.32		
	1200	180	16.87	2.9	68.62	2.99		
	1350	180	17.45	2.5	99.40	3.72	26.72	20.66
17	300	122	14.90	3.4	14.839	0.999		
	600	161	15.35	3.7	28.18	1.71		
	900	164	16.90	3.0	53.47	2.30		
	1050	184	18.72	2.6	66.98	1.41		
18	600	143	16.95	2.8	31.41	1.35		
	900	176	17.20	2.9	50.23	1.98		
	1050	176	17.87	2.0	67.70	2.26	29.95	12.84
19	600	136	17.37	2.6	36.39	1.38		
	900	167	17.05	3.1	45.76	1.87		
	1200	187	17.57	2.9	69.63	2.42	28.77	12.94
20	900	158	16.60	3.1	43.68	2.03		
	1200	184	17.27	2.9	67.56	2.60		
	1350	191	17.42	2.6	77.92	2.92	26.68	15.29